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ผลของบรรจุภัณฑ์ดัดแปลงสภาพบรรยากาศแบบแอคทีฟต่อคุณภาพของมะเขือเทศระหว่างการเก็บรักษาที่อุณหภูมิต่ำ

Effects of Active Modified Atmosphere Packaging on Quality of Tomatoes (*Lycopersicon esculentum*) during Cold Storage

Matshidiso Masopa[1] ธรรมรัตน์ ปราณอมรกิจ[1] และ วิรงรอง ทองดีสุนทร[1,2,*]

Matshidiso Masopa[1], Thamarath Pranamornkith[1] and Wirongrong Tongdeesoontorn[1,2,*]

บทคัดย่อ

มะเขือเทศ (*Lycopersicon esculentum*) มีอัตราการหายใจและมีการผลิตเอทิลีนเพิ่มขึ้นเมื่อสุกซึ่งทำให้เกิดการสูญเสียคุณภาพได้เร็ว งานวิจัยนี้ศึกษาผลของการใช้บรรจุภัณฑ์ดัดแปลงสภาพบรรยากาศแบบแอคทีฟ (active MAP) ที่มีการใช้แผ่นปลดปล่อยก๊าซคาร์บอนไดออกไซด์ความเข้มข้นต่างๆ (CO_2-pad) ในมะเขือเทศความสุกระยะเขียว-ส้ม โดยมีชุดการทดลอง ได้แก่ T1= ชุดควบคุม (มะเขือเทศในถุง LDPE โดยไม่มี CO_2-pad) เปรียบเทียบกับการใช้ CO_2-pad ในสัดส่วนต่างๆ ดังนี้ T2 = สัดส่วนเดี่ยว ($NaHCO_3$ 0.139 กรัม + กรดซิตริก 0.111 กรัม), T3 = สัดส่วนสองเท่า, และ T4 = สัดส่วนสี่เท่า ณ อุณหภูมิ 6±1 °C การศึกษานี้แสดงให้เห็นว่าการเพิ่มความเข้มข้นของก๊าซ CO_2 ในชุดการทดลอง T4 ร่วมกับการเก็บที่อุณหภูมิ 6±1 °C สามารถชะลอการเปลี่ยนแปลงค่าสี ลดการผลิตเอทิลีนและอัตราการเน่าเสียของผลมะเขือเทศได้ดีกว่าชุดการทดลองอื่นๆ แต่ไม่มีความแตกต่างกันในปริมาณของแข็งทั้งหมดที่ละลายน้ำได้และปริมาณกรดแอสคอร์บิก นอกจากนี้มะเขือเทศที่เก็บรักษาใน T4 พบความนิ่มลงของผลและอาการฉ่ำน้ำสูงกว่าชุดการทดลองอื่นตั้งแต่วันที่ 16 ของการเก็บรักษาเนื่องจากอาการสะท้านหนาวร่วมกับความเสียหายจากก๊าซ CO_2 จากผลการทดลองแสดงว่า active MAP ที่มีการใช้ CO_2-pad T4 ร่วมกับการเก็บที่อุณหภูมิ 6±1 °C สามารถช่วยยืดอายุการเก็บของมะเขือเทศได้จาก 8 วัน เป็น 16 วัน แต่จำเป็นต้องศึกษาอุณหภูมิและความเข้มข้นของก๊าซ CO_2 ที่เหมาะสม เพื่อป้องกันการเกิดความเสียหายจากอาการสะท้านหนาวและก๊าซ CO_2 ต่อไปในอนาคต

คำสำคัญ: บรรจุภัณฑ์ดัดแปลงสภาพบรรยากาศแบบแอคทีฟ แผ่นปลดปล่อยก๊าซคาร์บอนไดออกไซด์ อาการผิดปกติทางสรีรวิทยา

Abstract

During ripening, tomato (*Lycopersicon esculentum* Mill.) respiration and ethylene production rise, accelerating postharvest quality loss. In this work, the active modified atmosphere packaging (active MAP) was tested by placing different concentrations of CO_2 emitter (CO_2-pad) in packed mature green-light pink tomatoes. Treatments consisted of T1 = control (tomatoes in LDPE bag without active agent) compared to other treatments with CO_2-pad in different ratios, as follows: T2 = single ratio (0.139 g $NaHCO_3$ + 0.111 g citric acid), T3 = double ratio (0.278 g $NaHCO_3$ + 0.222 g citric acid), and T4 = quadruple ratio (0.556 g $NaHCO_3$ + 0.444 g citric acid) and stored samples at 6±1 °C (88-93% RH). The results showed that CO_2-pad of T4 can retain color values, reduce ethylene production rate as well as delay the decay rate of tomatoes better than other treatments when stored at 6±1 °C. However, there was no significant difference in total soluble solids, and ascorbic acid content in all treatments over storage periods. Some adverse effects were found when the tomatoes were kept in T4, which showed a higher incidence of fruit softening and water soaking during cold storage (after 16 days of storage) caused by chilling injury and CO_2 injury. The results demonstrated the beneficial impact of an active MAP, particularly the T4 treatment, combined with a low temperature of 6±1 °C, on the extension of tomatoes' shelf life from 8 to 16 days. Nevertheless, certain issues must be considered, including the potential for chilling and CO_2-induced damage. It is crucial to do future study to examine the most effective temperature and concentration of CO_2 in order to protect against these disorders.

Keywords: active modified atmosphere packaging, carbon dioxide emitter, physiological disorders

[1] สำนักวิชาอุตสาหกรรมเกษตร มหาวิทยาลัยแม่ฟ้าหลวง 333 หมู่ 1 ต.ท่าสุด อ.เมือง จ.เชียงราย 57100

[1] School of Agro-Industry, Mae Fah Luang University, Chiang Rai, 57100, Thailand

[2] ศูนย์วิจัยนวัตกรรมบรรจุภัณฑ์อาหารและวัสดุชีวภาพ มหาวิทยาลัยแม่ฟ้าหลวง 333 หมู่ 1 ต.ท่าสุด อ.เมือง จ.เชียงราย 57100

[2] Research Center of Innovative Food Packaging and Biomaterials, Mae Fah Luang University, Chiang Rai, 57100, Thailand

Introduction

Tomatoes (*Lycopersicon esculentum* Mill.) are a globally important fresh and processed vegetable. The global production of fresh tomatoes was 189.134 million metric tons in 2021 on 5.1 million hectares. However, this crop has a limited postharvest life due to rapid physiological changes during ripening. Modified atmosphere packaging (MAP) reduces O_2 and increases CO_2 to delay respiration, ripening, ethylene production, softening, and compositional changes, preserving tomato quality and extending shelf life (Fagundes *et al*., 2015). The carbon dioxide-releasing system reduces respiration and microbial development (Ozdemir and Floros, 2004). Sodium bicarbonate and citric acids are employed in vegetable sachets to release CO_2 (Vilela *et al*., 2018). There is little research on how active packaging with modified environment affects tomato quality and shelf life. Thus, this study investigates the use of active modified atmosphere packaging (CO_2 emitter) to preserve tomato quality during cold storage.

Materials and Methods

1. Materials

The experiment employed fresh tomatoes (mature green to light pink) from Lan Muang market in Chiang Rai with uniform color, size, and no defects. LDPE bags and sodium bicarbonate, citric acid, and sodium hypochlorite were bought.

2. Methods

The optimum content of sodium bicarbonate and citric acid were weighed ($NaHCO_3$: citric acid T2 = single ratio (0.139 g: 0.111 g), T3 = double ratio (0.278 g: 0.222 g), and T4 = quadruple ratio (0.556 g: 0.444 g), mixed, and packed in the absorbent pad sachets. Tomatoes were washed in tap water and dipped into a sodium hypochlorite solution (200 ppm). Six fruits were packed in LDPE bags with (T2, T3, T4) and without (T1) CO_2-emitting pads, sealed, and placed in a cold storage at 6±1°C, 85-90 % RH for 28 days. The qualities of tomatoes were determined every 4 days (3 replications/treatment/sampling day). Quality parameters were assessed as follows:

2.1 Headspace gas composition

The O_2 and CO_2 concentrations were determined by Dansensor CO_2/O_2 gas analyzer.

2.2 Color

Peel color including L*, a*, b*, and hue angle (h) values were measured by MiniScan EZ 4500L colorimeter (Hunter Lab Miniscan instrument, USA).

2.3 Damage Incidence and severity

Damage Incidence (DI) and severity (DS) (Tilahun *et al*., 2021) were analyzed per replicate using the following formulas:

$$\text{DI (\%)} = \frac{No.\ of\ Infected\ Fruits}{Total\ No.\ of\ Fruits} \times 100$$

$$\text{DS (\%)} = \frac{(\text{Severity rating} \times \text{Number of tomato fruit clusters in the rating})}{\text{Total number of tomato fruit clusters assessed}} \text{x Highest DS score}(4 \times 100)$$

2.4 Quality Determination

Other qualities of tomatoes, such as firmness, weight loss, ethylene production, respiration rate, ascorbic acid, total soluble solids and titratable acidity, were also analyzed following the method of D'Aquino *et al*. (2016).

2.4 Statistical analysis

The experiment was a complete randomized design (CRD). Statistical analysis was done using SPSS 17 program (SPSS, USA). Analysis of variance (ANOVA) and significance test of the mean used Turkey's Multiple Range Tests. The results were measured at $p<0.05$ statistical significance.

Results and Discussion

1. Gas composition

Figure 1 displays the concentration levels of CO_2 and O_2 in packed products with and without a CO_2 emitter. It reveals that on day 0, the CO_2 concentration was higher in T4, T3, and T2 than in T1 (control) because of the CO_2 released from the pads. The increase in CO_2 levels and the decrease in O_2 levels indicate that tomatoes produced CO_2 and consumed O_2 during storage, respectively. After day 12, the balance of gas permeabilities and respiration achieves an equilibrium level for the gases. Suparlan and Itoh (2003) reported similar results, observing a significant decline of O_2 level and an increase in CO_2 in the gas composition of the package of fresh cut tomatoes under MAP.

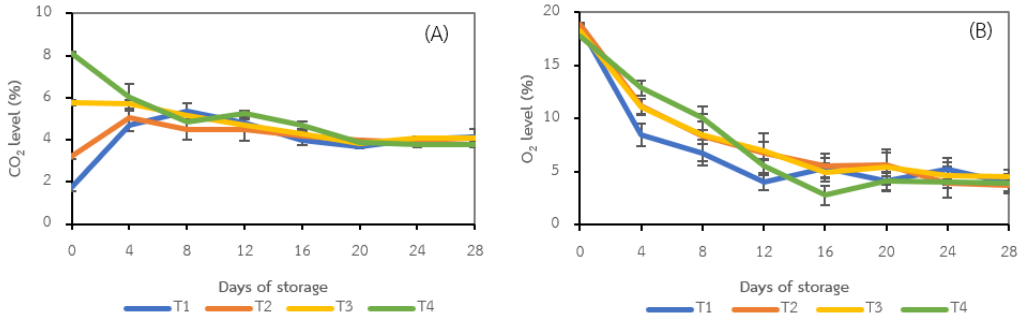

Figure 1 CO_2 and O_2 concentrations inside LDPE packages of tomatoes during storage period of 28 days at 6±1 ℃ (* shows the significance of treatments according to Turkey's test $p<0.05$).

2. Peel color

In all storage conditions, L* declined and a* and b* raised (Figure 2). This value change suggests tomato ripening. T4 had a lower a* value than other treatments, indicating a slower green-to-red color transition. As the days went on, the hue angle decreased from 95° (green-yellowish) to 55° (orange-pink). During storage, T4 had the lowest hue angle changes (73° to 65°) compared to T2 (68° to 60°), T3 (70° to 60°), and control (63° to 55°), indicating a significant delay in tomato ripening ($p<0.05$) due to higher CO_2 early on. D'Aquino *et al*. (2016) also found that the color angle lowering during cherry tomato storage. MAP delayed tomato color changes by slowing the metabolic processes that breaks down chlorophyll pigments and synthesizes lycopene and β-carotene during storage (Olveira-Bouzas *et al*., 2021).

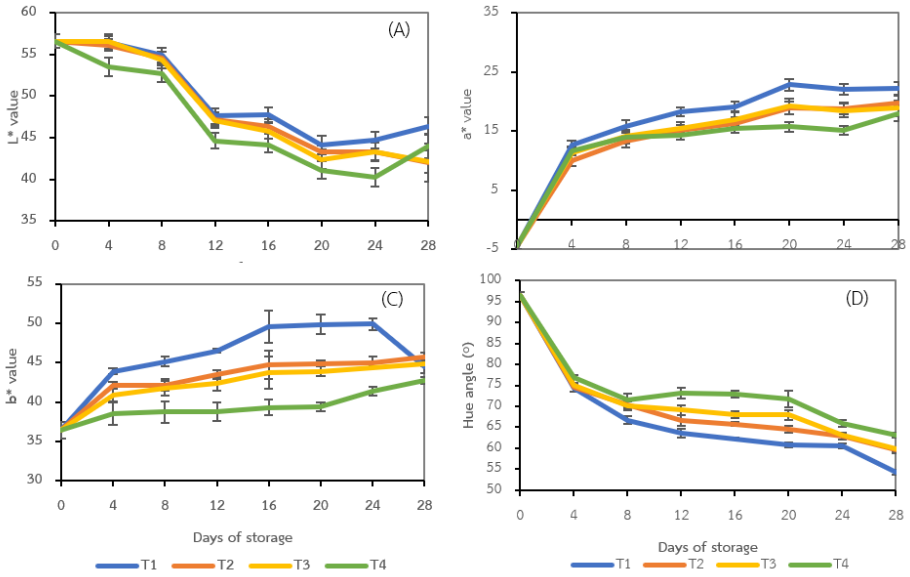

Figure 2 Peel color changes L* (A), a* (B), b* (C) and hue angle (D) of tomatoes in LDPE films during storage period of 28 days at 6±1℃.

3. Damage incidence and severity

The presence of damage started to show in the control 3.33% after 8 days of storage (Figure 3). Damage incidence (DI) continued to increase throughout storage in other treatments except for T4 which displayed the DI after 20 days of storage (3.33%). Day 23 DI was highest for T2 (80%), followed by the control (70%), T3 (43.33%), and T4 (23.33%). DI and damage severity (DS) exhibited a similar pattern. The study found that CO_2-pads, especially T4 with greater ratios, effectively reduced decay and chilling damage in tomatoes stored at 6±1°C. Liguori *et al*. (2015) studied the effects of passive and active MAP conditions on quality of minimally processed table grapes during cold storage and found that an increase of CO_2 in packages can cause harm to the tissues making grapes more prone to decay. The author observed that high CO_2 partial pressure in PET1 and PET2, along with lower O_2 concentrations, led to accelerated decay, anaerobic respiration, soluble sugar degradation, weight loss, and decreased sensory quality. However, in our study tomatoes in all the treatments showed some softening and water soaking symptoms during cold storage.

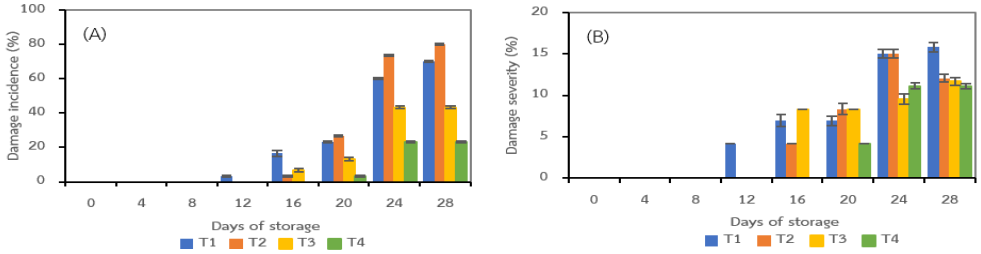

Figure 3 Damage incidence (A) and damage severity (B) of tomatoes packed in LDPE films during storage period of 28 days at 6±1°C.

Conclusion

Combining active MAP with low temperature (6±1 °C) delayed ripening and preserved tomato quality during cold storage. When utilizing a CO_2 emitter, the greatest CO_2 (T4) concentration was achieved. The escalated CO_2 significantly delayed peel color changes and reduced fruit damage. Further inquiry is needed to determine the cause of the softening and water soaking symptoms on tomatoes during cold storage.

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